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Science Fairs: A Qualitative Study of Their Impact on Student Science Inquiry Learning and Attitudes Toward STEM

Abstract

Little is known about the impact of science fair participation on student science inquiry learning. Furthermore, there is only a small research base relating to science fair participation and student attitudes toward science, technology, engineering, and mathematics (STEM) careers and coursework. In this study, 41 seventh-grade science fair contestants from three schools participated in focus group sessions to qualitatively assess their interest in STEM careers and coursework and their understanding of science inquiry.

Science fair participation increased student understanding of science inquiry, and positively influenced the attitudes of the majority of students in the study toward STEM courses and careers. The strengths of the science fair programs were a focus on science inquiry as well as student choice in choosing and carrying out projects. However, for a sub-group of students, the stress level they experienced as they worked on their projects resulted in negative attitudes toward STEM fields. The length and complexity of the science fair process was of concern for many students, but especially so for this sub-group. It is possible that an undertaking of the length and complexity of a typical science fair project is not appropriate for all students in this age group. Alternatives for students include carrying out several shorter projects, rather than one large project, or working with partners or small groups. These strategies could serve the larger goals of increasing student science inquiry understanding and increasing positive student attitudes toward STEM fields in a more age-appropriate manner.

Keywords: science fair, science inquiry, inquiry learning

Introduction

In the wake of globalization and the need for the United States to remain technologically and economically competitive, increasing the number of students entering science, technology, engineering, and mathematics (STEM) fields has been a focus of much research and study in recent years (STEM Education Coalition, 2012). However, STEM careers require formal and rigorous academic preparation beginning in high school. One metaphor for this preparation has been of a STEM pipeline, where students trickle out based on their course choices in high school (Simpson, Koballa, Oliver, & Crawley, 1994). In turn, high school course choices play a role in the student interest in STEM careers (Sadler, Sonnert, Hazari, & Tai, 2014). Maltese and Tai (2010) found that one key to increasing the number of students entering the pipeline may be to engage their interest during middle school. However, interest alone is not enough to ensure that students persevere in pursuing a STEM career. They also need science inquiry skills and understandings (National Research Council, 2000), and they need to lay the foundation of these skills and understandings in middle school. Science fair participation may play a role in increasing both interest in and understanding of STEM fields.

Literature Review

Coverage of science fairs in the popular press is relatively common, but tends to be limited to opinion pieces that are either supportive (Calmes, 2012) or critical (Craven & Hogan, 2008). Books and guides to assist students and parents in conducting successful projects are common; a search for “science fair” at a community library yielded over 50 titles. However, the research base regarding the effectiveness of science fairs in supporting student learning and attitudes toward STEM is scant. There are a few studies that relate interest in science to the pursuit of a science career (Archer, et al., 2010; Riegel-Crumb, Moore, & Ramos-Wada, 2011; R.D. Simpson, et al., 1994), but none explicitly mention science fair participation as an influence in science interest.

In 2013, the Next Generation Science Standards (NGSS) were released (NGSS Lead States). These standards were developed from a document published by the National Research Council (NRC)—*A Framework for K-12 Science Education* (2012). In this document, the NRC has defined three dimensions of science education, one of which is “science and engineering practices” (p.3). These practices include how to ask a scientific question, plan and conduct a scientifically valid investigation, analyze and interpret data, and communicate results. The Illinois Junior Academy of Science (IJAS)

Policy and Procedure Manual (2014) describes the alignment of their science fairs with the NRC science and engineering practices as well as individual NGSS standards. In addition, the IJAS states as its mission "…to present science as rational observation and systematic investigation of natural phenomenon…" (p. 5). The development of critical thinking and logical reasoning are also given as goals. This alignment reveals an underlying assumption that science fair participation may lead to increased understanding of science inquiry. However, there is little research to either support or disprove this assumption.

This We Believe is a position paper that was first published by the Association for Middle Level Education (AMLE) in 1982, and has since been revised (Association for Middle Level Education, 2010, 2014). The essential attributes, goals, importance, and key characteristics of an effective middle-level education program need to take into account not only the developmental level of the students, but what they need to learn in order to be prepared to function as adults. According to AMLE (2010), some components of such a middle-level education program are: engaging in and understanding the process of inquiry, asking questions for which there may not be only one correct answer, assessing and interpreting information from a variety of sources, and using critical thinking skills. All of these components are also found in the science and engineering practices as defined by the NRC (National Research Council, 2012), the NGSS standards (NGSS Lead States, 2013), and the IJAS (Illinois Junior Academy of Science, 2014).

The National Science Teachers Association (NSTA) encourages schools to de-emphasize the competition aspect of science fairs and asserts that they should be voluntary (National Science Teachers Association, 1999, 2003). Abernathy and Vineyard (2001) found that most science fairs were compulsory, but question whether students would voluntarily participate in such a difficult and time-consuming undertaking without external motivation. In fact, they state, "what may appear to be coercion may really be an opportunity" (p.274).

The motivations of science fair participants were investigated in a pair of studies (Czerniak & Lumpe, 1996; Czerniak, 1996), with a focus on perceived behavioral control and cognitive theories of motivation. A primary concern was that the level of coercion involved in science fair participation, and the possible resulting psychological harm, were greater than the perceived benefits of increased science skills (Czerniak & Lumpe, 1996). Questions were also raised by the researchers regarding the effect that a poor performance could have on a student's self-esteem and attitude toward science, as well as issues resulting from the use of volunteer judges who vary in their expertise and ability to fairly evaluate student work (Czerniak, 1996).

Reis, Dionne, and Trudel (2015) investigated the role of performance anxiety in science fair participation, and found it at all stages of the process, from choosing the topic to presenting the results. They determined that this anxiety dissipates as students repeatedly engage in the process. These studies did not assess student science inquiry learning and understanding or attitudes toward STEM fields.

Several studies investigated student motivation to pursue science and STEM careers. Forrester (2010) surveyed and interviewed college freshmen regarding their motivations for choosing their majors. Science competition participants displayed higher self-efficacy in science and were more likely to choose engineering as a major. However, these students indicated that the encouragement of teachers, parents, and peers were also important in their choice of career. Adult support also played a key role in a study by Ansbacher, Li, and Roth (2010). Students who experienced adult support were more likely to have a positive "science identity" and persist in their pursuit of a STEM career (p. 567).

In a study of eighth-grade students who were part of the 2003 Trends in International Math and Science Study (TIMSS) cohort, Riegle-Crumb et al. (2011) found that science enjoyment was not a strong predictor of science achievement, but was a predictor of science career aspirations. R.D. Simpson et al. (1994) also found that parent/teacher/peer encouragement, as well as pursuing science hobbies as a child, led students to enter the STEM career pipeline. In addition, Maltese and Tai (2010) found that adult encouragement was important to student interest in science, especially for females. The importance of teachers in nurturing science interest was a common theme for both genders.

The research indicates, then, that the enjoyment of science and strong support from adults are influential in determining if a student will opt to pursue a STEM career. Students who experience success in their scientific pursuits may be more likely to find science enjoyable. However, the question of whether science fair participation leads to increased interest and enjoyment in science has not been studied. Neither has science fair participation ever been studied as a variable that might influence students to pursue STEM careers.

Subjects

In this study, a total of 41 subjects participated in focus groups. The subjects included seventh-grade students of both genders in intact classrooms from three schools. Each focus group consisted of 4 to 13 students. The participants were drawn from schools participating in Illinois Junior Academy of Science (IJAS) science fairs. Schools were contacted via e-mail. Requests from schools for additional information were supplied via e-mail, phone calls, and meetings.

Data Collection

The purpose of data collection for the study was to assess the influence of science fair participation on student attitudes toward STEM courses and careers and their science inquiry understanding. The students were invited to participate in focus groups in order to uncover the direct effects of science fair participation on their science inquiry understanding and attitudes, since a science fair is not likely to have been their only science experience. The focus group format was chosen as it was thought to be less intimidating for students in this age group than one-on-one interviews (Barbour, 2008). The questions were designed according to best practices as suggested by Krueger and Casey (2000) and Krueger (1998).

Focus Group Questions

1. What was the topic of your science fair project?
2. Thinking back, what was your favorite part of the science fair?
3. List three things you learned about science from the science fair.
4. Did you feel that you learned a lot about science by participating in the science fair? In what way?
5. Do you think that you would like to become a scientist? What makes you think this?
6. Has participating in the science fair changed your mind about becoming a scientist? In what way?
7. If you could tell me one thing about your science fair experience, what would it be?

The focus group interviews took place after the students had participated in their school and/or regional science fairs. The classroom teachers solicited volunteers for the focus groups. All students who participated signed assent forms and provided parental consent. The focus groups were held during regular class time, were about 30 minutes long, and were audiotaped. Students were given the opportunity to leave if they wished. At one school the teacher was present in the room during the focus group, as per school policy. The students were given a list of the focus group questions, and were given three to five minutes to read and think before the session began. For questions 1 and 2, all of the students were given an opportunity to respond or pass. For question 3, the students compiled a list on chart paper. Questions 4-6 were addressed in an open discussion format. All of the students were given the opportunity to respond to question 7, but could pass if they wished. Follow-up questions were asked as appropriate. At the end of the session, students were invited to share any parting thoughts, and then thanked for their time.

Data Analysis

A word processing program was used to transcribe the audio recordings of the focus group sessions. The comments in the transcripts were grouped into "organizational categories" according to the protocol described by Maxwell (2005, p.97). The organizational categories were: comments relating to STEM, comments relating to science inquiry skills, and other comments. Within each organizational category, the comments were further sorted by "substantive" categories that provided insight into the participants' attitudes and beliefs (Maxwell, 2005, p. 97).

A summary of the themes and subthemes is shown in Table 1. The students were not required to answer the questions, so the numbers given in the tables are the number of students who chose to answer that particular question.

Understanding of Science Inquiry

The subtheme of *increase in general science knowledge* was defined as responses in which the students indicated that they had learned science content. An example of this type of response is: "I got to learn about how energy builds up, and how it flows, and how it stops, and how it can light the simplest bulbs."

The subtheme of *evidence of procedural knowledge* was defined as speaking about how to conduct an experiment. These responses showed an awareness of how to design and conduct an experiment without including specific details. Examples of these responses are: "I learned how to use variables."; "I learned more about the planning part and the process of it."; and, "…we had to go through the procedure and the hypothesis and figure out how to do the actual experiment."

An example of a response that implied that the student engaged in *designing an experiment and collecting and analyzing data* was: "I learned that natural sponges are more absorbent that synthetic sponges." In order to reach such a conclusion, the student would have had to conduct an experiment, collect data, and analyze the data. Some students went into great detail as they described their experimental process.

Evidence that a student was able to *evaluate the correctness of a hypothesis* required that the student use the word "hypothesis" correctly. Examples of such comments were: "I learned that sometimes you can be really wrong about your hypothesis. I mean, yes, my hypothesis was true, but the product that I thought would be the least good actually came out to be second best."; and, "My hypothesis was perfectly correct. I tested people by themselves, or in groups of two, or in big groups."

Several of the science fair students displayed an understanding of science inquiry as hypothesis-testing through designing and conducting an experiment. The evidence suggests that the students not only engaged in the formal steps of a scientific process, but gained an understanding of these steps through the development and execution of their science fair projects.

Attitudes Toward STEM Subjects and Careers

Eight science fair students indicated an interest in a science or a science-related career.

One student commented:

> Maybe because I think it's interesting to learn about new things, how you can do it yourself, and then you come up with this hypothesis, and you come up with a conclusion, and you did it all yourself. And it's something new you didn't know.

Another commented:

> I would say yes because even though the field of medical stuff really interests me, I also think that experimenting and doing lots of searching, I think that sounds fun, like archeology. That science really sounds fun too.

One student stated:

> So I would like to become a scientist, so I like engineering, and a key part of engineering is science. So that would kind of make me a scientist, so the reason that I would like to become that is because I just enjoy it.

Table 1. Data Analysis: Themes and Subthemes

Theme	Subtheme	Number of Students Commenting (N=41)	Indicator	Example
Science Inquiry	Increase in general science knowledge	n = 15	Students indicated that he/she had learned science content	"I got to learn how energy builds up, and how it flows…"
	Evidence of procedural knowledge	n = 8	Speaking in general about how to conduct an experiment	"I learned how to use variables."
	Design experiment, collect and analyze data	n = 27	Evidence that the student had conducted an experiment, collected data, and analyzed the data	"I learned that natural sponges are more absorbent than synthetic sponges."
	Evaluate correctness of hypothesis	n = 7	Student used the term "hypothesis" correctly	"My hypothesis was perfectly correct…"
Attitudes toward STEM courses and careers	Desire to pursue a career in science	*n* = 23 Yes = 7 Science-related field (as defined by student) = 1 No = 11 Don't know/ need more information = 4	Student indicated an interest/no interest in a science or science-related career	"It seems too difficult to be a scientist or science teacher."
	Influence of science competition on the desire to pursue a career in science	*n* = 14 Positive = 9 Negative = 5	Student indicated that science competition influenced his/her desire to pursue a career in science	"I'd say that after doing the science fair it more inclined me to become a scientist…"
Other Themes	Favorite part of the science fair process	See Table 2	Student mentioned components of the science fair process, including background research, experimentation, making the presentation board, and presenting	"I liked to organize the board how I wanted it…"
	Hard Work		Student commented about the effort involved in science fair	"Science takes a lot of effort, but it was worth it."

Several students perceived science careers as being stressful and difficult. Such comments included: "Science is very stressful."; "I don't think that I would like to be a scientist because I stressed out over my experiment, more stressed out than any project that I had ever done."; and, "It seems too difficult to be a scientist or a science teacher."

One student commented:

> I'm going to have to say no because I feel like I would struggle a lot, because I'm also not very patient and stuff. And because I don't think I would be able to understand what I would be doing.

For 9 of 14 students, participation in a science fair resulted in a more positive perception of pursuing a science career. However, few of the students chose to reply to question 6—*Has participating in the science fair changed your mind about becoming a scientist? In what way?* Positive comments included: "I'd say that after doing the science fair, it more inclined me to become a scientist because it answered some of my questions." and, "Before, in previous grades, I was not as interested in science because we didn't learn anything exciting. But now that I've done actual experiments and stuff, I think it is more exciting."

Another student commented:

> I don't think I would become a scientist, but doing science fair has kind of grabbed by attention a little more on that. I don't think that I would devote my life to science, but it kind of grabbed my attention a little.

In general, the negative comments made by the students related to their perception of science as being difficult and stressful. Student comments included: "I learned a lot of interesting facts, and I want to keep learning, but it seems too hard."; "Well, before, I thought that being a scientist was not as hard, but you have to take a lot of time, and it is hard, actually."; and, "Not really, I found out that my data and everything [was] pretty disorganized, and I had to like at the last minute, organize it all. I couldn't really become a scientist." The experience of participating in a science fair was positive for some students, negative for others, and for some it was both positive and negative.

One student commented,

> Pretty much yes and no, but mostly no, because I'm pretty disorganized, I would probably struggle with being organized. But yes, because, you know, I want to be a doctor someday. I think that science could help me along that path.

Based on student comments, the researchers are concerned that the science fair experience may have discouraged some students who may have otherwise had positive attitudes toward science and scientists.

Science Fair Students' Favorite Part of the Project

In addition to the primary focus group questions, the students were asked about their favorite part of the science fair experience as a clarifying/follow-up question. A summary of their responses is in Table 2.

The background research portion of science fair projects was where many students demonstrated that they learned science content. For example, a student stated: "Because of all the things that I did, what I didn't think that science would do was the effects of skin health. But when I read through the articles, it got really cool. I really found it interesting." Hands-on experimentation and interacting with test subjects were cited as reasons for choosing *conducting the experiment* as the favorite part of the process. Students had a tendency to refer to "the procedure" and "the experiment" interchangeably. Sample comments are: "I like the procedure because I kind of liked hands-on things. Even though it took a really long time because of the subject of my project, I thought that it was really fun."; "I liked doing the testing because you got to find what different people thought."; "I liked seeing the changes."; and, "I just like it because it was the most suspenseful part because you really don't know what your results are going to be."

The favorite parts of the project cited by about half of the students were making the display board and presenting their work, which could be considered the less scientific parts of the process. The opportunity to be creative in sharing their work and being able to personalize their work were cited as the reason for the popularity of these activities. For example, students concluded: "I like making my board the best because I could design the board any way I wanted as long as I did pretty much everything my teacher told me to do, so it was pretty fun and creative."; and, "I liked to organize the board how I wanted it. And making sure that everything was precise and how I wanted it." Pride in sharing their accomplishments and improving their presentation skills were seen as benefits of presenting their work. Student comments included: "One of the key things that I got out of the science fair was like presentation skills."; "I feel like I learned a lot because now I feel like I'm more comfortable talking to people because I was able to talk to a lot of people the night of the science fair."; "Presenting isn't as scary as it seemed to be."; and, "I got to show what I'd learned so far and present it to other people."

One student summarized his/her overall experience with the project:

> The part where you test everything, that is the most fun part. Presenting is really nerve wracking, you get nervous. Writing the paper is pretty tedious. It's hard to do. Now I know in the future when I do a science fair project I'm going to avoid testing people because there are so many variables. You can't control them all.

Table 2. Favorite Part of the Science Fair Process

Component	Number of responses (n = 38)
Doing background research	5
Conducting the experiment	12
Making the presentation board	8
Presenting	13

Hard Work

The student comments were mixed about the hard-work aspect of the competition. There were 19 students who indicated that the work was worthwhile. Examples of these comments are: "A lot was really hard, but it was fun in the end."; "I would say that I thought that it was a good experience for me, but it was a lot of work that I really didn't want to do."; and, "Science takes a lot of effort, but it was worth it."

One student commented,

> One thing I remember…was that it was a ton of work, and most of the time I was really disorganized. And I had to redo things a lot. But eventually I kind of got the hang of it. And it turned out to be more successful than I thought that it would be.

Negative comments regarding the work involved in a science fair project were made by 15 students. These comments focused on the perceived difficulty of the project, and the amount of time and stress involved. Such comments included: "I thought that it was really stressful, really time consuming too."; "I think that it was pretty difficult, and I don't ever want to do it again."; and, "The science fair really stresses you out. It wasn't an enjoyable part, I didn't really like it."

One student commented,

> I actually thought that it was going to be more fun than it was. And then I realized that it is a lot of hard work, a lot of researching, a lot of late nights, and doing science. I thought that it was going to be more fun. It was a lot of hard work.

For the students, an underlying discomfort was revealed in even some of the positive comments: "…work I didn't really want to do" and, "It was more successful than I thought it would be."

Discussion

Increasing student interest in STEM careers and improving student science inquiry skills and understandings are stated goals of science fairs (Illinois Junior Academy of Science, 2014). Even though success in STEM careers is contingent on having science inquiry skills (Anderson, 2007), having such skills does not guarantee that students will aspire to these careers. The transfer of learning is dependent on intrinsic motivation (Bransford, Brown, & Cocking, 2000) and interest leads to more persistence when students are engaged in challenging tasks (Hidi & Renniger, 2006). Hazari et al. (2010) and Kanter (2010) have shown that the key ingredients in student interest in STEM careers are the opportunity to engage in relevant, hands-on, real-world experiences. In addition to skills and interest, students who aspire to STEM careers need to prepare for them through a rigorous course of study (University of Illinois, 2015). The combination of skills, interest, and preparation are keys to success in STEM careers.

According to the Association for Middle Level Education (AMLE), an appropriate educational program for adolescents should give students the opportunity to engage in the inquiry process (AMLE, 2010). While it would seem that a science fair would provide a venue for this to happen (Bellipani & Lilly, 2003; IJAS, 2012), just because students participate in such an event does not guarantee that they will increase their understanding of the inquiry process. Quantitative measurement of science inquiry skills is problematic as well. Very few assessments are available for use in classrooms, and even the national assessments (e.g., National Assessment of Educational Progress and Trends in International Mathematics and Science Study) only have a small number of questions that are designated as relating to science inquiry skills (National Center for Education Statistics, 2012a, 2012b). Therefore, this study employed qualitative measurement of student science inquiry skills and understandings through focus group interviews. Many of the students indicated that they did increase their science content knowledge, and could show their understanding of the science inquiry process through the use of appropriate terminology and detailed descriptions of the design and execution of their projects.

Past research regarding the attitudes of science fair participants has been concerned with their attitudes toward the event itself, rather than STEM subjects and careers (Czerniak, 1996; Cerniak & Lumpe, 1996). Some of the students found science fair participation to be affirming and inspiring in their aspirations for a STEM career. However, there was a subgroup for whom the science fair experience served as evidence that a STEM career was not of interest to them. The length and complexity of the project seemed to be the cause of much of their distress. The work of Czerniak and Lumpe (1996) echoes this result, in that 61% of the students indicated wasted time and 20% of the students expressed hard work (as defined by the students) were barriers to enjoyment of the process. When asked about their favorite aspect of the science fair process, slightly less than half of the students indicated that they enjoyed doing the background research and/or conducting the experiment.

According to the National Research Council one of the key components of the science inquiry process is sharing results (1996, 2000, 2012). Czerniak and Lumpe (1996) found that 13% of the students indicated that a positive aspect of their science fair experience was improving their presentation skills. In the current study, of the students who responded to the question about their favorite part of the science fair, slightly more than half chose making the display board and presenting their work. These students cited the opportunity for creativity as the reason for their choice.

Conclusions and Recommendations

In talking with the students, it was apparent that many of them were sincerely interested in the results of their projects. They could speak in great detail about the processes they used to develop and execute their projects, and their discourse showed that they had a general understanding of a scientific process and could use terms such as "hypothesis" correctly. The opportunity afforded by science fairs for students to choose a topic and design investigations are strengths of the program, and are supported by AMLE (2010). Unfortunately, for some students, negative attitudes toward science were a consequence of their participation. The length and complexity of the undertaking seemed to be the chief complaint, and led to the question of whether science fairs as currently conducted are appropriate for this age group. Another issue concerning age appropriateness of science fairs is the individual nature of the projects—success and failure is dependent solely on the efforts of the individual. Such a situation can be intimidating to some students.

We recommend that science fair organizers retain student choice and opportunities for communicating their results, while making the event more age-appropriate by allowing for shorter/smaller/more frequent projects and encouraging students to work with a partner or small group. This structure would preserve the positive aspects of science fairs, such as student choice in topic and experimental design, increased science content knowledge, hands-on experience employing the science inquiry process, and improved verbal and written communication skills. The shorter/smaller/more frequent projects developed with a partner or small group would serve to alleviate some of the negative effects of traditional science fairs as found by Czerniak and Lumpe (1996), and would support the development of social skills recommended by AMLE (2010).

Further research is needed to determine the effect of science fair participation on student career choice. This research could be conducted as a longitudinal study of a cohort of science fair participants or as a retrospective study of adults engaged in STEM careers.

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